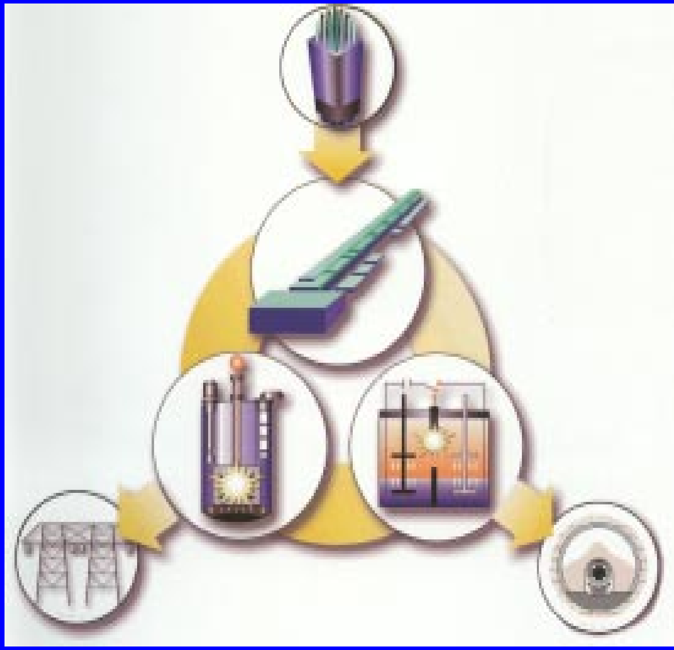

Advanced Accelerator Applications

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University Programs Leader
Los Alamos National Laboratory

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Through the AAA Program, the U.S. Joins International Efforts

to evaluate the potential of Partitioning & Transmutation along with advanced nuclear fuel cycles

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Advanced Accelerator Applications AAA

Systems Modeling projects future U.S. inventory of used fuel

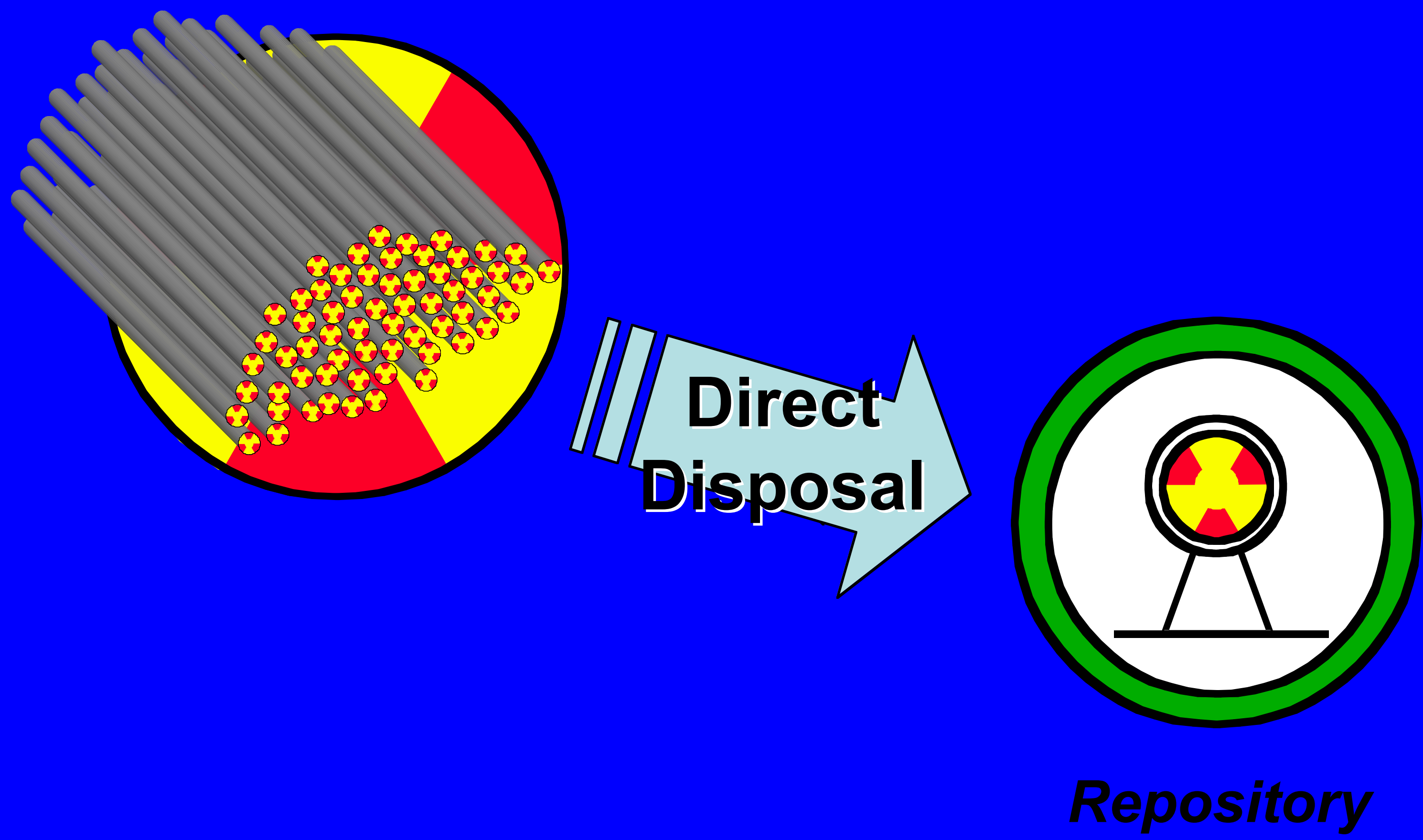
- ATW Roadmap: 87,000 tn, 2030s
- Life extensions: 144,000 tn, 2050s
- NEI Vision 2020: 120,000 tn 2030s
  >180,000 tn 2050s

What do we do with it?

Options for disposal of nuclear "waste"

- once-through fuel "cycle," or
- **reduce, reuse, and recycle**
  - MOX-fueled LWRs or HTGCR
  - Accelerator-driven transmutation
  - Fast reactors (includes breeders)

Today's option: "once-through" fuel "cycle"



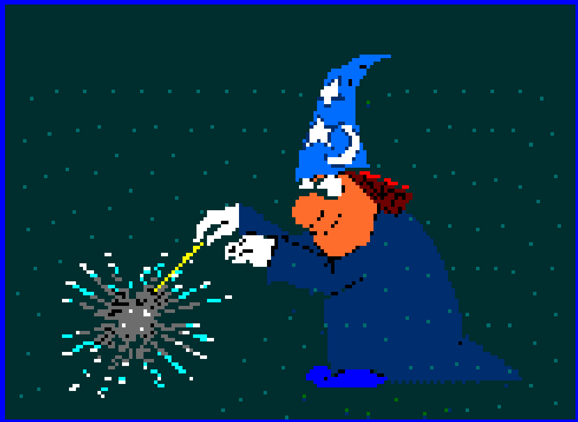
Direct disposal faces many challenges

- Political opposition
- Public acceptance
- Licensing and regulatory concerns
- Uncertainty in projecting out for hundreds of thousands of years

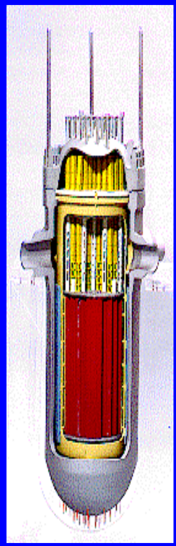
Transmutation of “waste” offers potential solutions to these challenges

Transmutation means
Nuclear Transformation

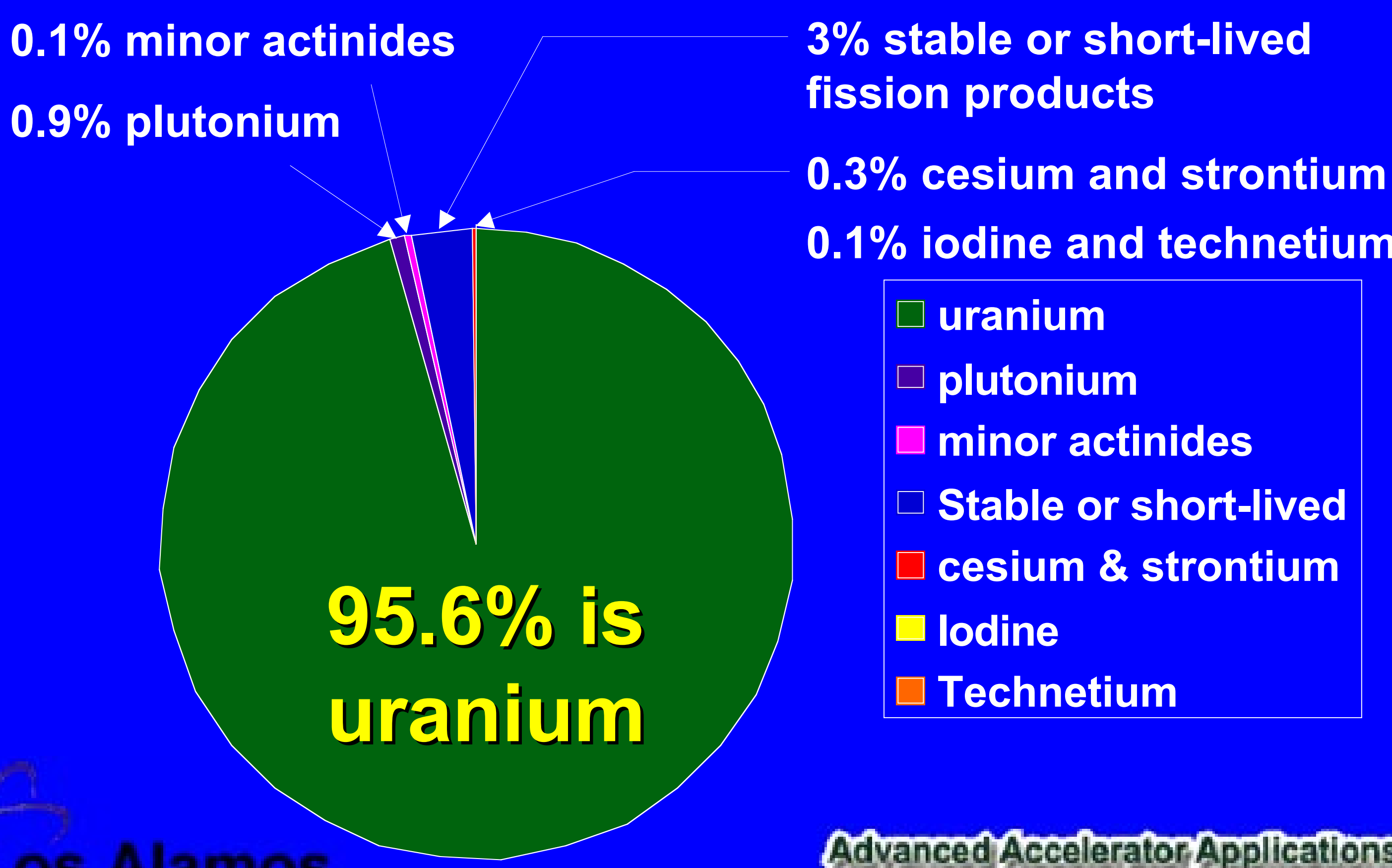
- changes the contents of the nucleus (protons and/or neutrons)
- natural (decay) or driven
- since before World War II - it's Not Hard!



Turn lead into gold? Just need a source of neutrons ….



Most long-term hazards are due to 1.1% of the used nuclear fuel

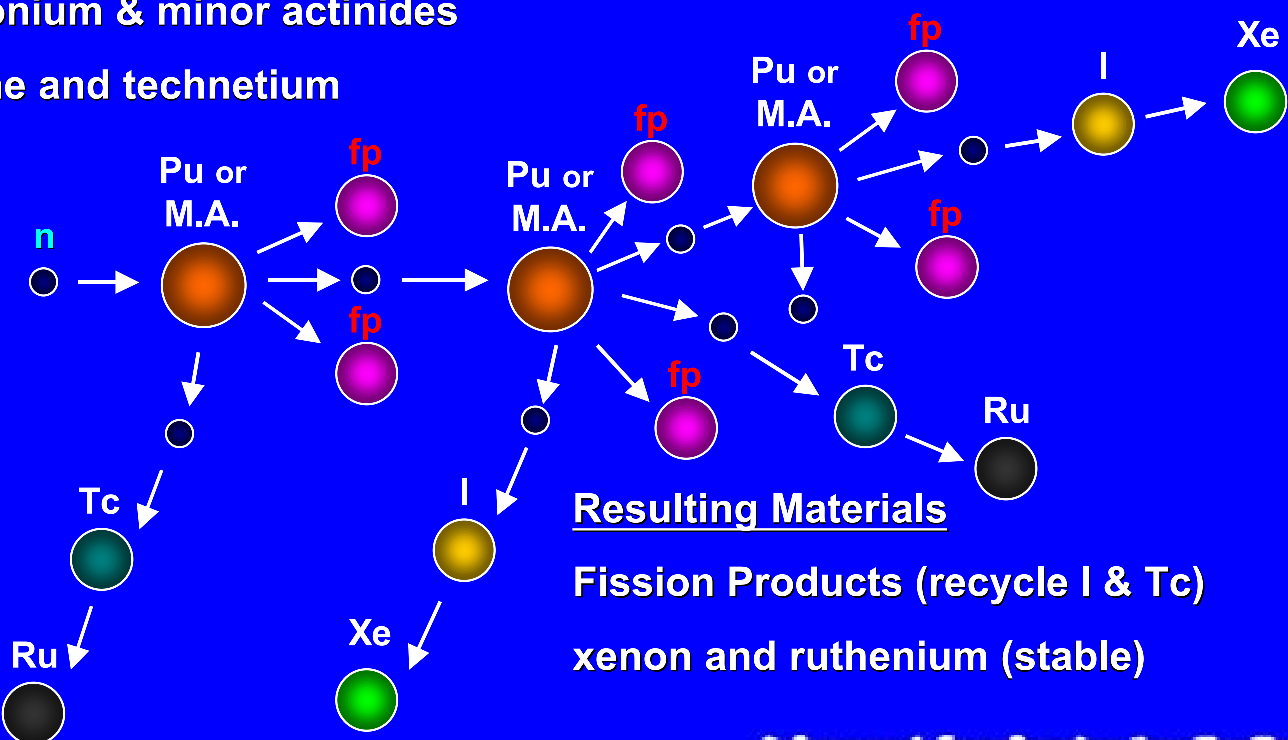


Pu and MA are fissioned, excess neutrons convert I and Tc to stable isotopes

Initial Materials

plutonium & minor actinides

iodine and technetium



Resulting Materials

Fission Products (recycle I & Tc)

xenon and ruthenium (stable)

The challenge is to transmute effectively:

thorough, clean, safe, and cost-effective

- near 100% conversion
- low losses
- accident free
- reduce waste toxicity and volume
- minimal impact to cost of the nuclear fuel cycle

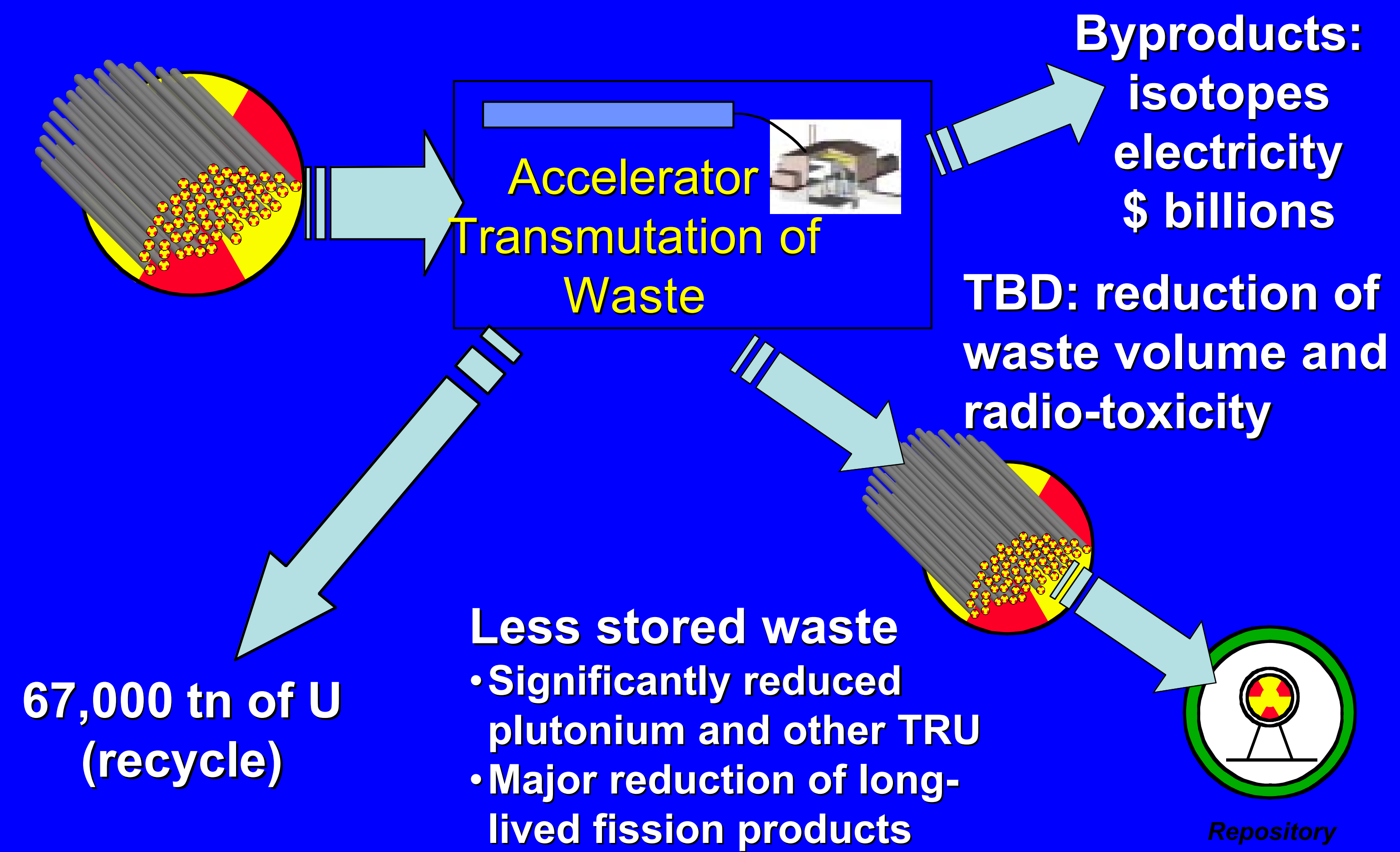
AAA Mission: conduct research, development and demonstration

- **transmutation of used nuclear fuel**
- **test bed to conduct nuclear R&D**
- **capability of producing other isotopes**
- **nuclear infrastructure and nuclear future**

The Transmutation Strategy:

- Partition used nuclear fuel
- Discard uranium and stable elements
- Form transmutation fuel from long-lived radionuclides
- Transmute long-lived radionuclides into short-lived or stable isotopes
- Manage remaining short-lived wastes for just a few hundred years

ATW Technology Can Lead to Reductions of Nuclear Waste



ATW can reduce projected doses, but defense waste reduces ATW impact

Impact on dose is reduced to about a factor of 10

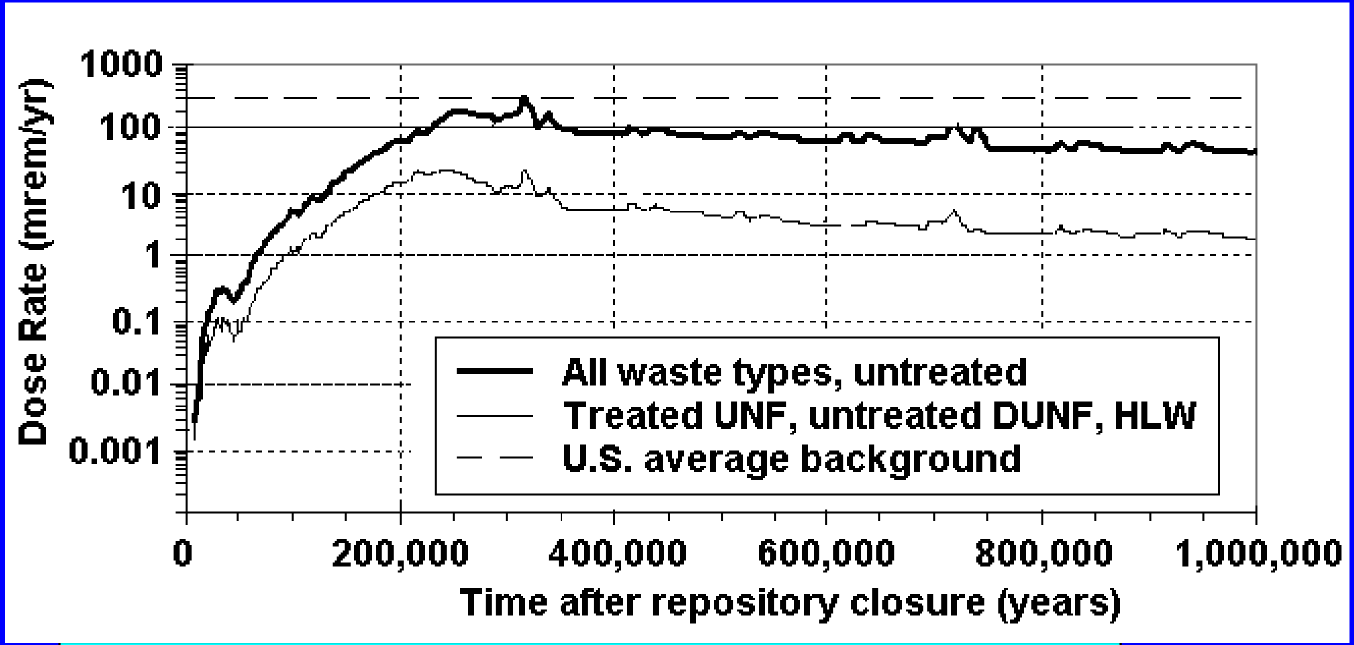


Figure 5.3. Individual Dose Rate (Adult, 20 km Distance, All Exposure Pathways) Comparison for the First Million Years after Repository Closure

To do this, ATW includes three major technology elements:

1) **Separations & Waste Forms**
   - aqueous or molten salt chemistry
   - glass, ceramic, or metal waste forms
2) **Accelerators**
   - linacs or cyclotrons
3) **Subcritical Transmuters**
   - fast, metal, gas, molten salt, thermal

Separations and Waste Forms

Separations processes are being investigated at ANL and LANL

- Aqueous: UREX
  - may be preferred for separation of used LWR fuel
  - does not separate Pu from MA
- Pyro-processing
  - similar to IFR
  - for used ATW fuel
- Others (FLEX, ...)

ATW separations provide stable waste forms

- Problem isotopes are separated, then
- some are transmuted
- while others can be combined to create long-lived, non-hazardous waste forms
  - optimum repository performance impact
  - combine some with massive amounts of zirconium
  - combine some in vitrified waste

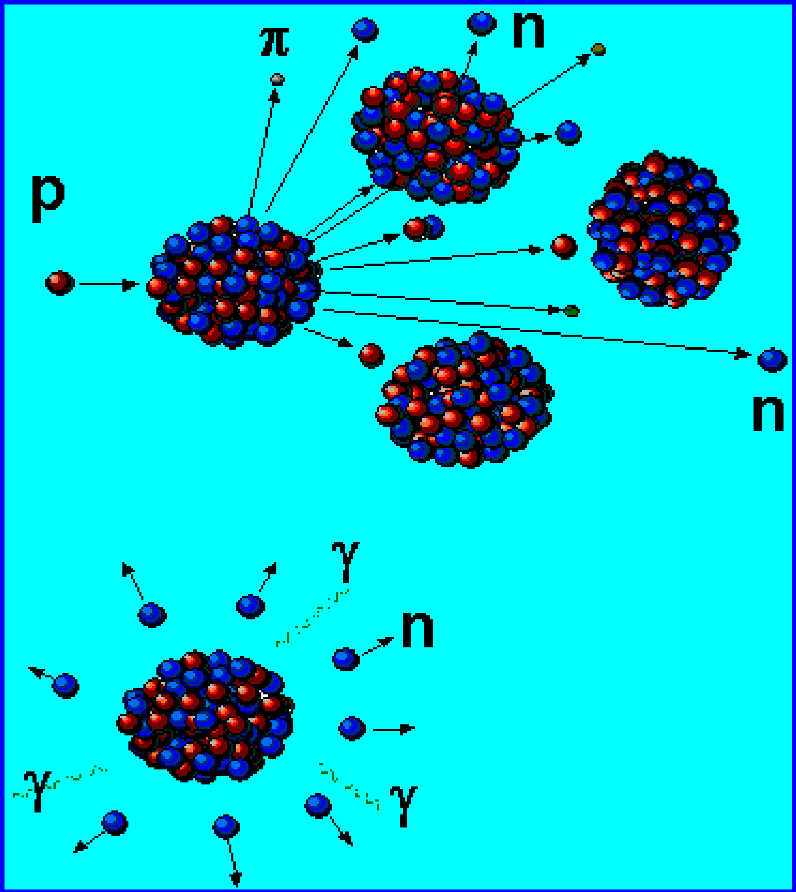
Accelerators

Accelerators will produce powerful beams of high-energy particles

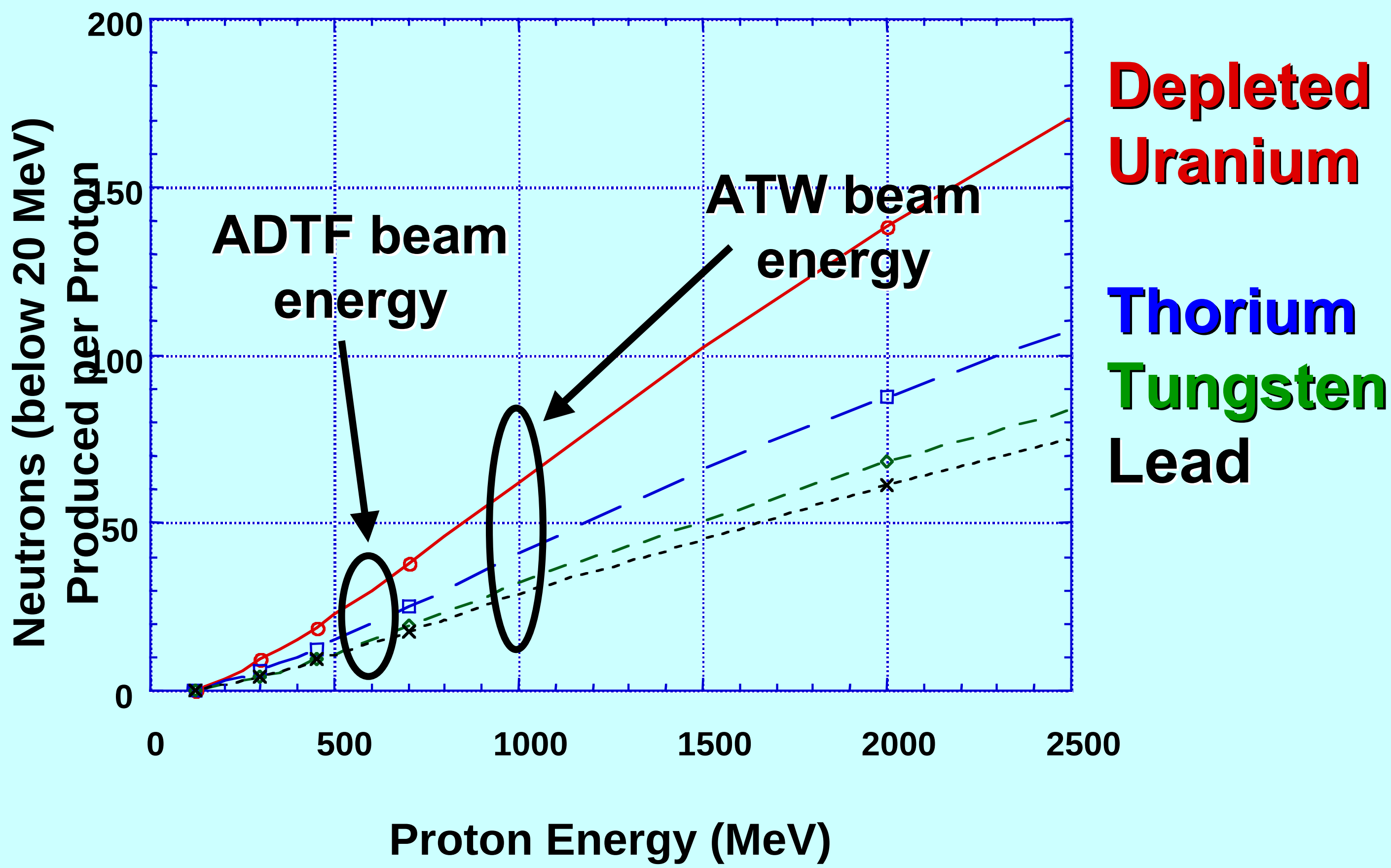
- 600 to 1000 MeV protons
- mA of current
- product is MW of beam power
- big and expensive
- how to turn that into neutrons for spallation?

Spallation & evaporation produce neutrons

- protons strike heavy nuclei
- knocked-out particles create a ‘cascade’
- residual nuclei ‘cool’ off by evaporation

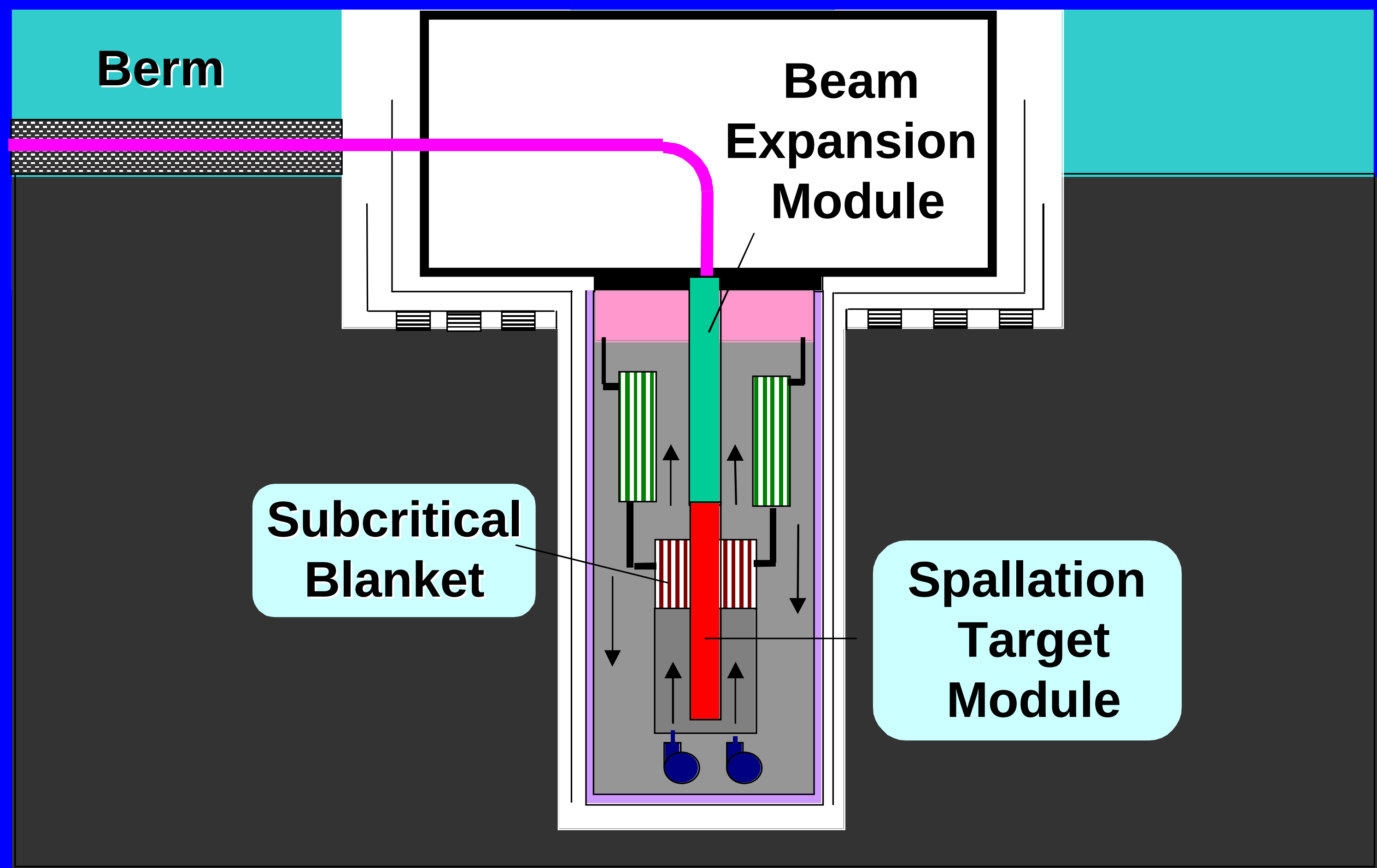


Heavier target materials yield more neutrons per proton

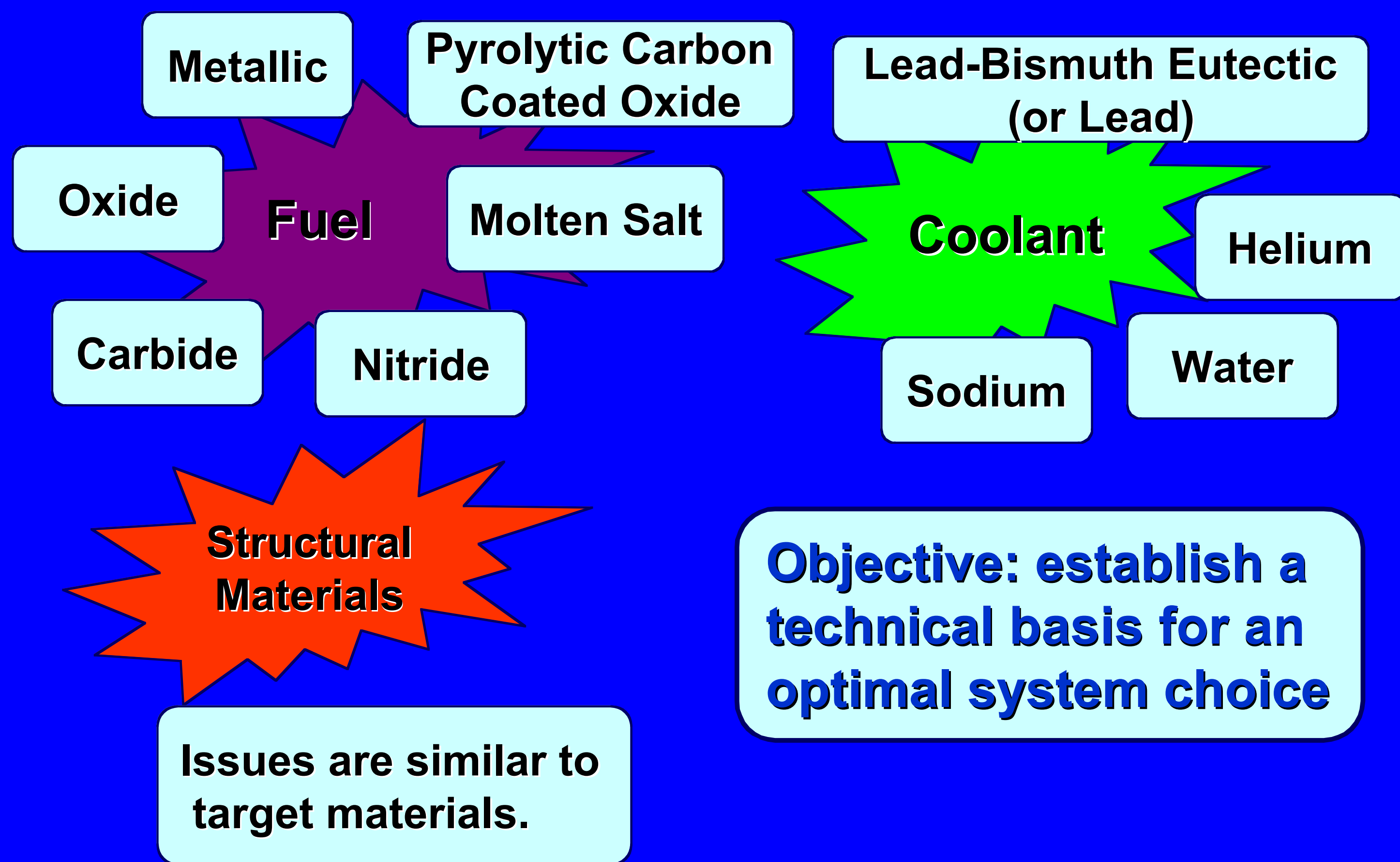


Transmuters (Targets & Blankets)

ATW beam expansion and spallation target modules in ATW transmuter



For the transmuter, the major challenge is fuel development



ATW subcritical capability adds flexibility

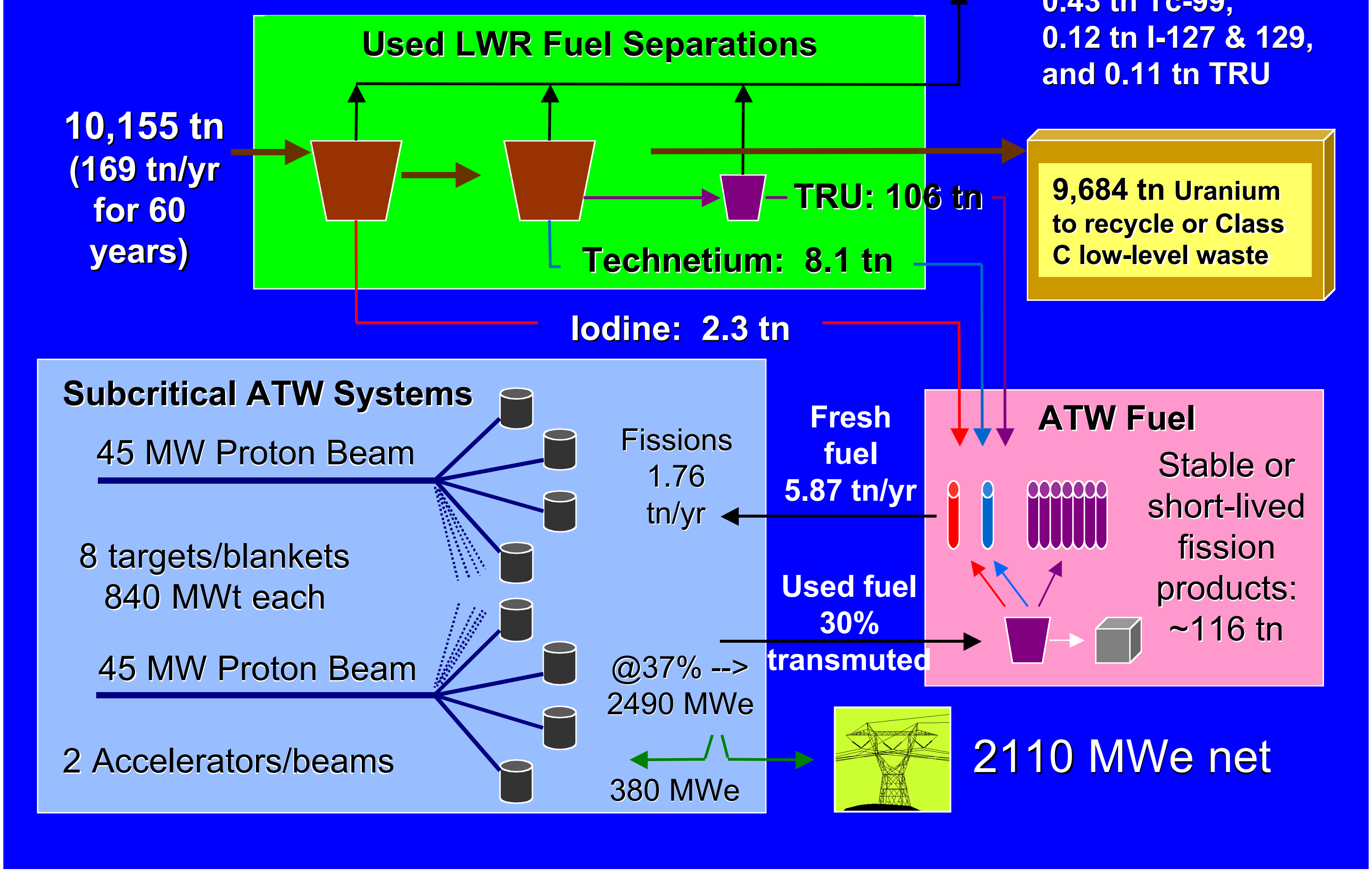
- Nuclear systems have always operated "critical"
- Subcritical capability adds flexibility
  - Can drive systems with low fissile content or high non-fissile burden
  - operate with fuel that could make critical systems unstable
  - compensate for large uncertainties or reactivity swings

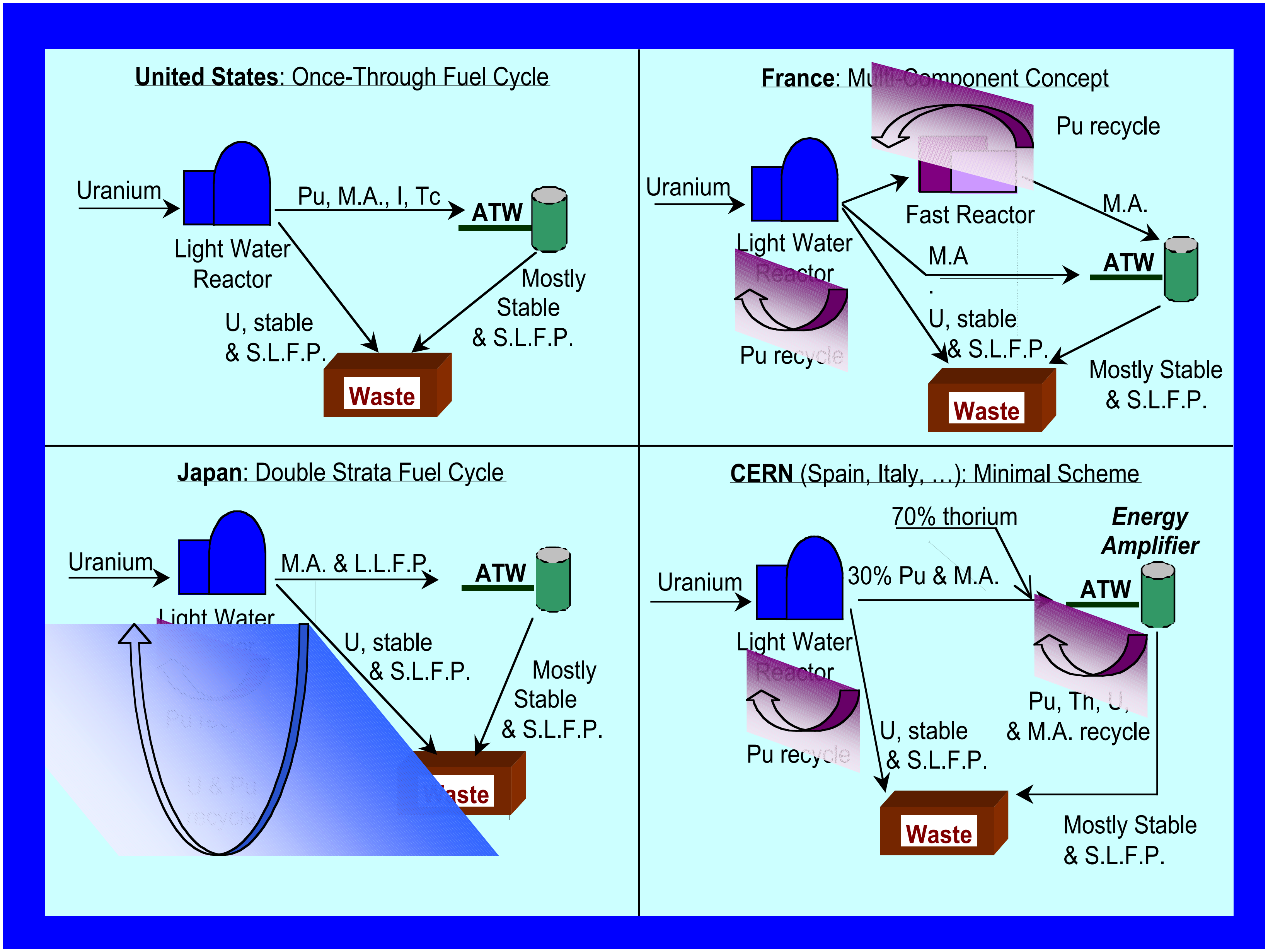
Subcritical operation option addresses fuel cycle issues

- jump-start systems with insufficient fissile content
- support advanced fuel cycles by transmuting wastes
- close-down cycles with depleted fissile content

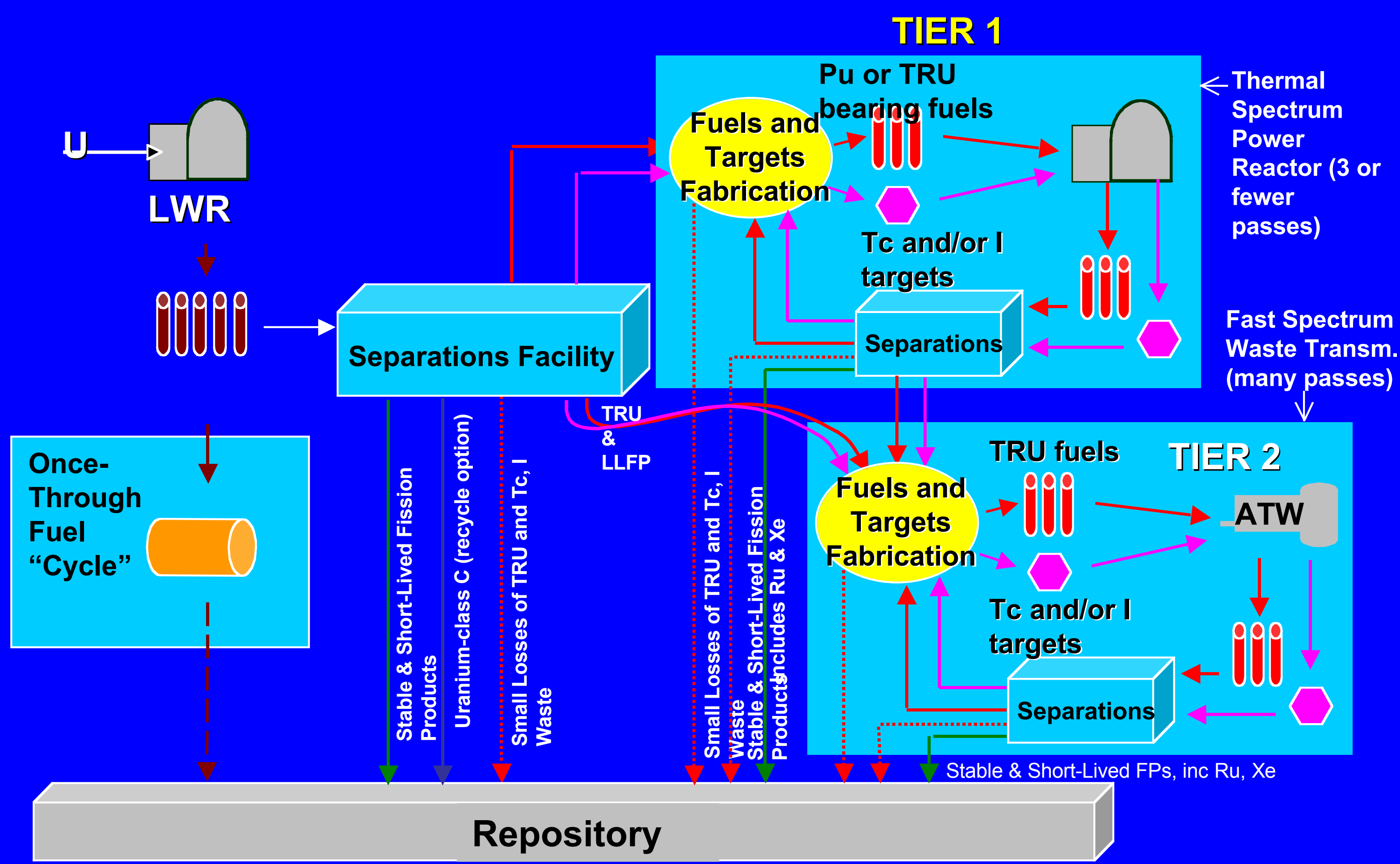
ATW Systems and Scenarios

Separations process for fuel discharged from current light-water reactors




United States: Once-Through Fuel Cycle
Uranium
Pu, M.A., I, Tc
ATW
Light Water Reactor
Mostly Stable & S.L.F.P.
U, stable & S.L.F.P.
Waste
France: Multi-Component Concept
Pu recycle
Uranium
Fast Reactor
M.A.
Light Water Reactor
M.A
ATW
Pu recycle
U, stable & S.L.F.P.
Mostly Stable & S.L.F.P.
Waste
Japan: Double Strata Fuel Cycle
Uranium
M.A. & L.L.F.P.
ATW
Light Water
U, stable & S.L.F.P.
Mostly Stable & S.L.F.P.
CERN (Spain, Italy, …): Minimal Scheme
70% thorium
Energy Amplifier
Uranium
30% Pu & M.A.
ATW
Light Water Reactor
Pu recycle
Pu, Th, U, & M.A. recycle
U, stable & S.L.F.P.
Waste
Mostly Stable & S.L.F.P.

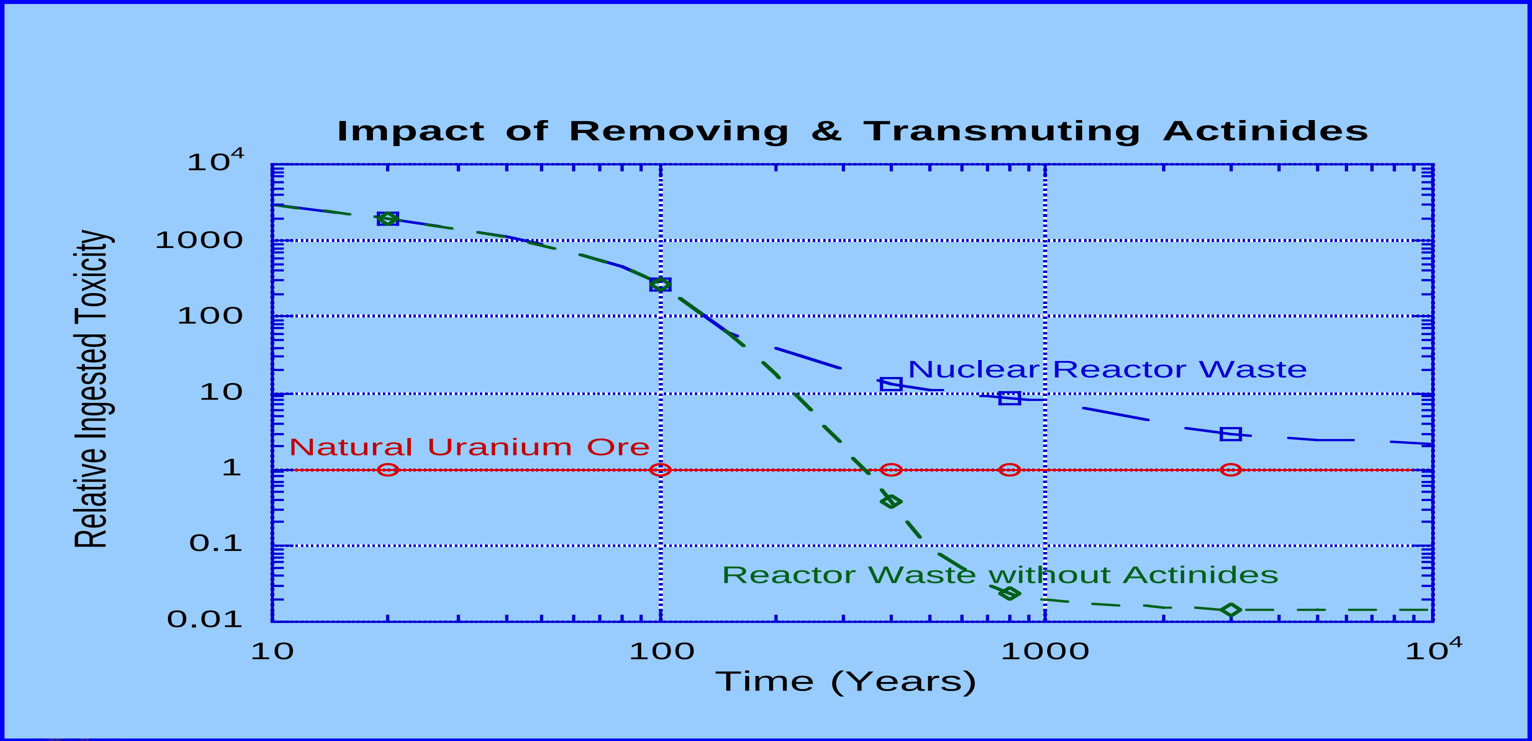
Multi-Tier Approach Using Thermal Spectrum Power Reactors to Transmute Pu May Improve Economics, but Increases Materials Flow Complexities



Partitioning & Transmutation are evaluated versus four goals

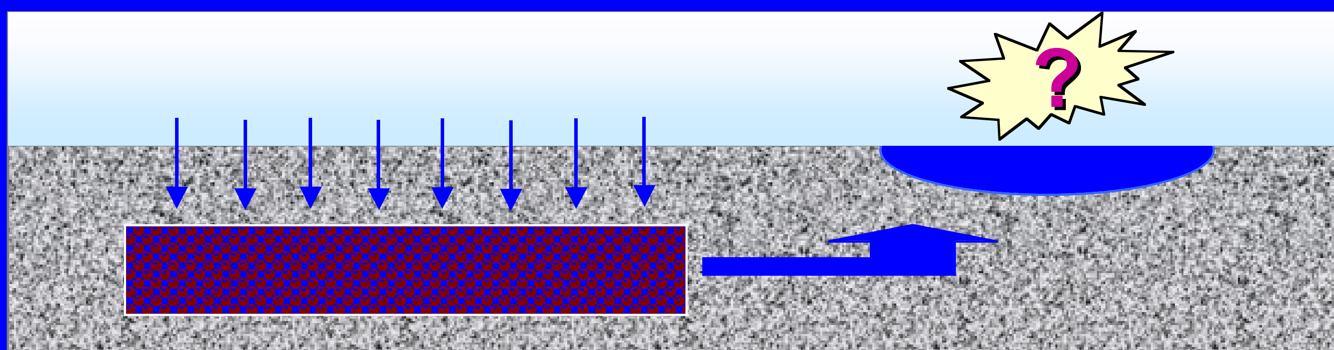
- Reduce toxicity of used nuclear fuel within lifetime of manmade containers
- Reduce long-term dose to inhabitants by transmuting mobile elements
- Deplete actinides to reduce attractiveness
- Improve prospects for a nuclear future

Reduce toxicity of spent fuel within lifetime of man-made containers and/or barriers (a few millennia)



Reduce maximum long-term dose

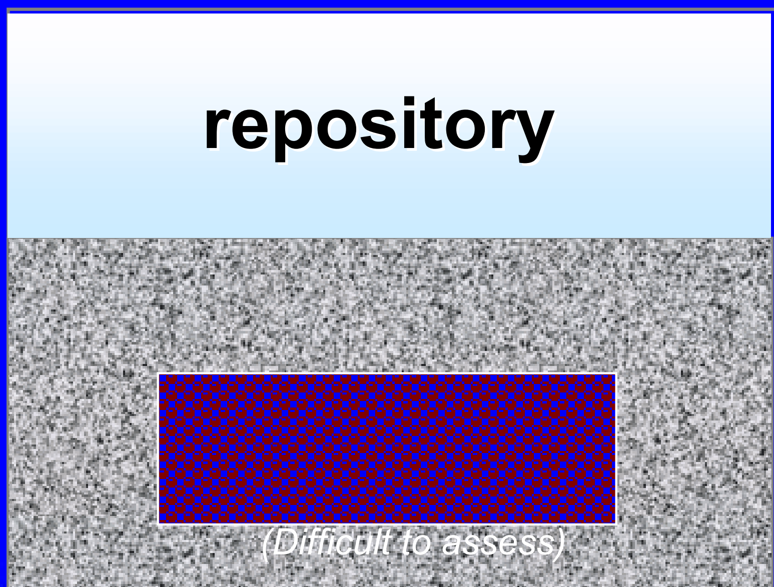
- to future inhabitants by
  - transmuting mobile elements or
  - placing into leach-resistant waste forms



Compare vs. natural background dose

Deplete content/mix of actinides in waste stream

- **Make it less desirable/attractive than alternate sources of fissile materials**



Alternate Sources?

Improve prospects for nuclear energy

- Integrate over time & across borders

Simpler, cheaper repositories

marginal cost impact

Near-term proliferation risk minimized

Near-term ES&H burdens manageable

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Advanced Accelerator Applications AAA

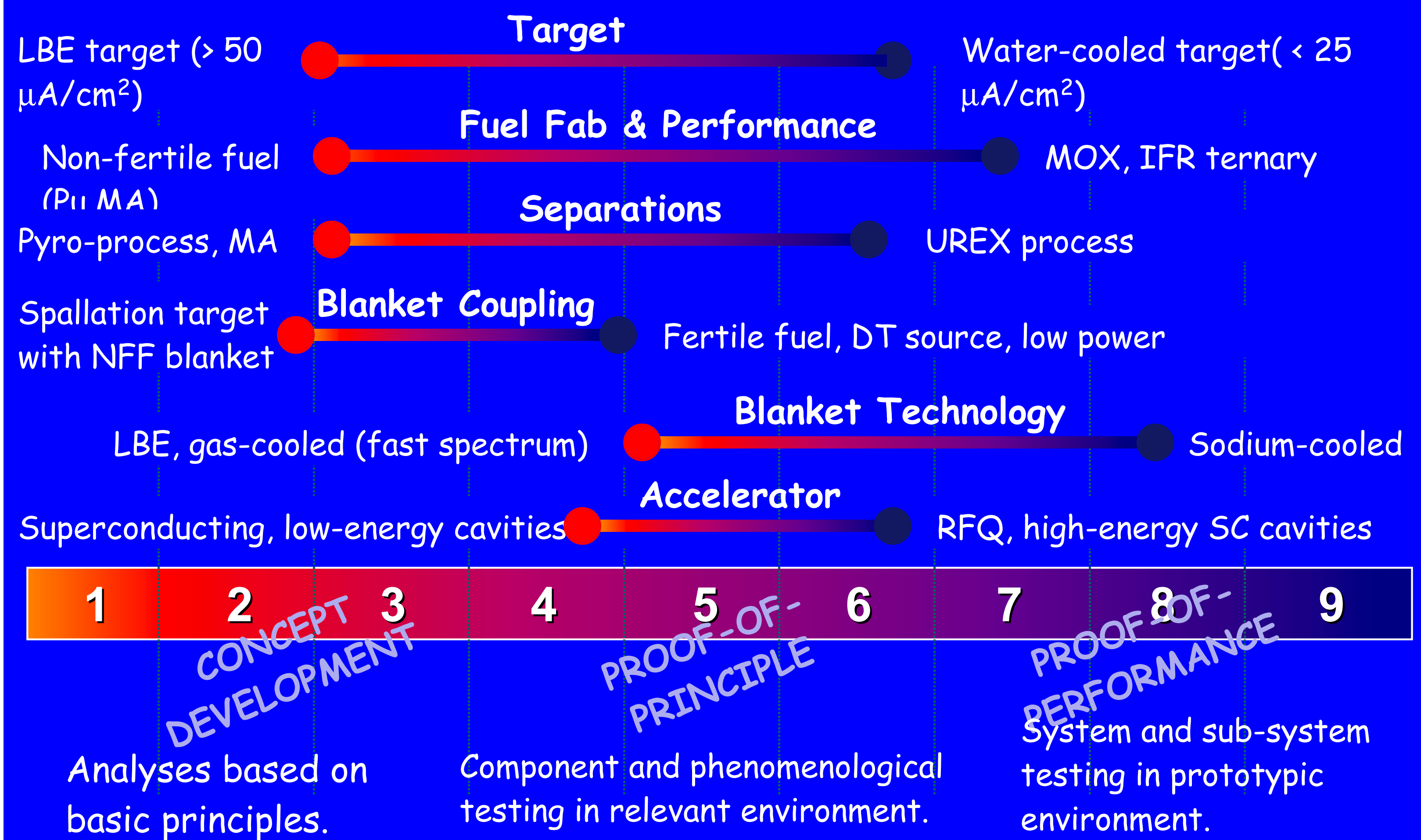
Why Invest in the AAA Program?

- Public support
- Good resource stewardship
- Augments current waste management strategy
- Brings U.S. back to forefront in nuclear science and technology
- Spin-off technologies, e.g. medical isotopes, may be as significant as the transmutation of waste

Cons (why not invest?)

- Cost--worthwhile R&D involves significant investment
- Other transmutation concepts exist
  - difficult to implement, less flexible, and narrower in scope
- Uncertainty--success of new technologies always entails uncertainty
- Proliferation?
  - (R&D should enlighten us)

The existing readiness level depends on the technology area and sub-system



AAA mission requires optimum use of nuclear infrastructure

Universities are key to AAA success

- Directed university research
- Fellowship Program
- UNLV & ISU Programs
- future University Research Program?
- how big is it?
  - ~$4 M FY01
  - >$7 M FY02

Potential for ten universities, $10 M, more than 100 students

- FY01: UT Austin, UC Berkeley, U of Mich, UNLV
- FY02: add NCSU, Idaho State
- UNLV: $4.5 M, 15 research projects, 3 new faculty, ~50 students
- Ten more AAA Fellowships
- Competitive URP in FY02?
- Other

Collaboration with the CEA, seven major work packages:

- WP 1: ADS Safety
- WP 2: Dedicated (Non-fertile) fuels
- WP 3: Target and Materials
- WP 4: Physics
- WP 5: Facilities
- WP 6: System Studies
- WP 7: Separations

Facilities to provide Proof of Principle and Proof of Performance

Approximate Time Scale:

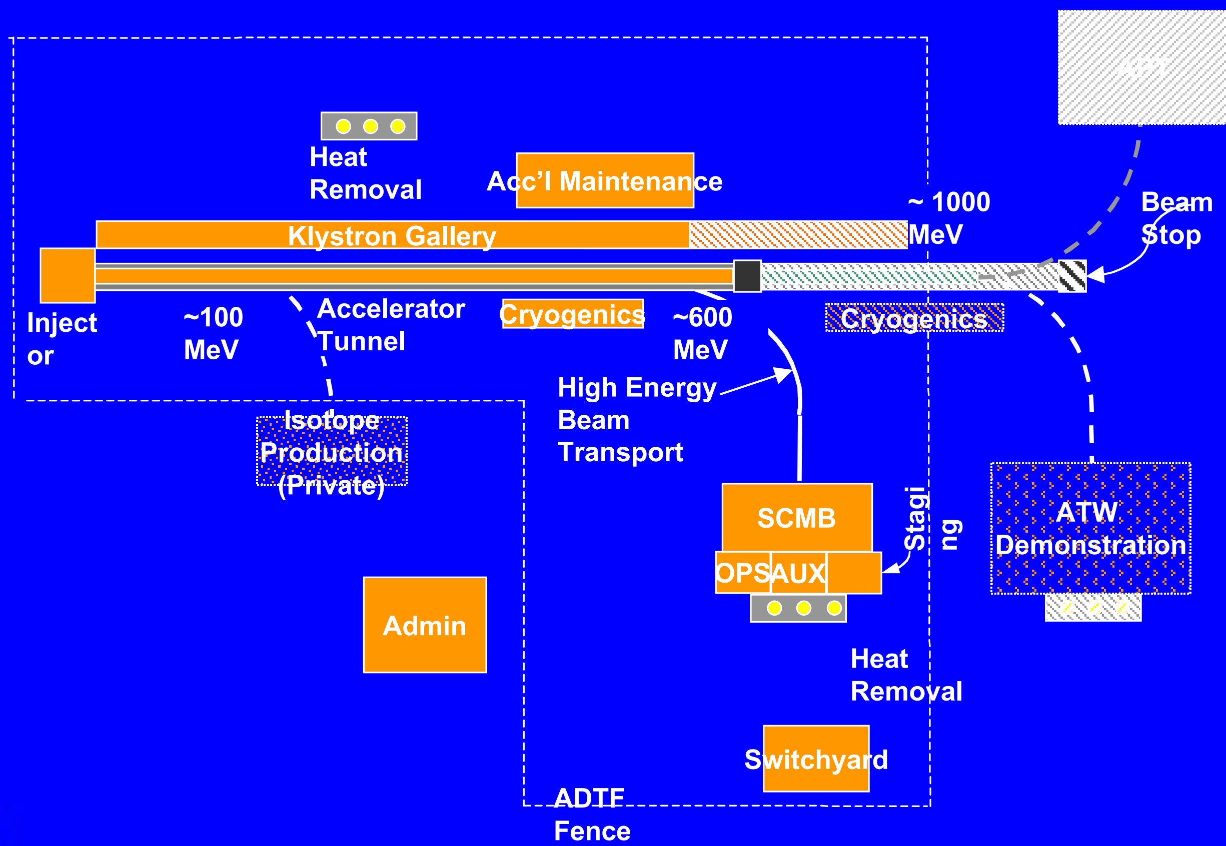
	3 to 5 years	10 to 20 years
	Scaled experiments: LANSCE, TREAT, MASURCA, MTL, ATR, PHENIX, BOR60, Blue Room, Hot Cells	ADTF plus fuel fab and separations facilities

Technology Readiness Level Scale:

1 2 3 4 5 6 7 8 9

Analyses based on basic principles	Component and phenomenological testing in relevant environment	System and sub-system testing in prototypic environment
CONCEPT DEVELOPMENT	PROOF-OF-PRINCIPLE	PROOF-OF-PERFORMANCE

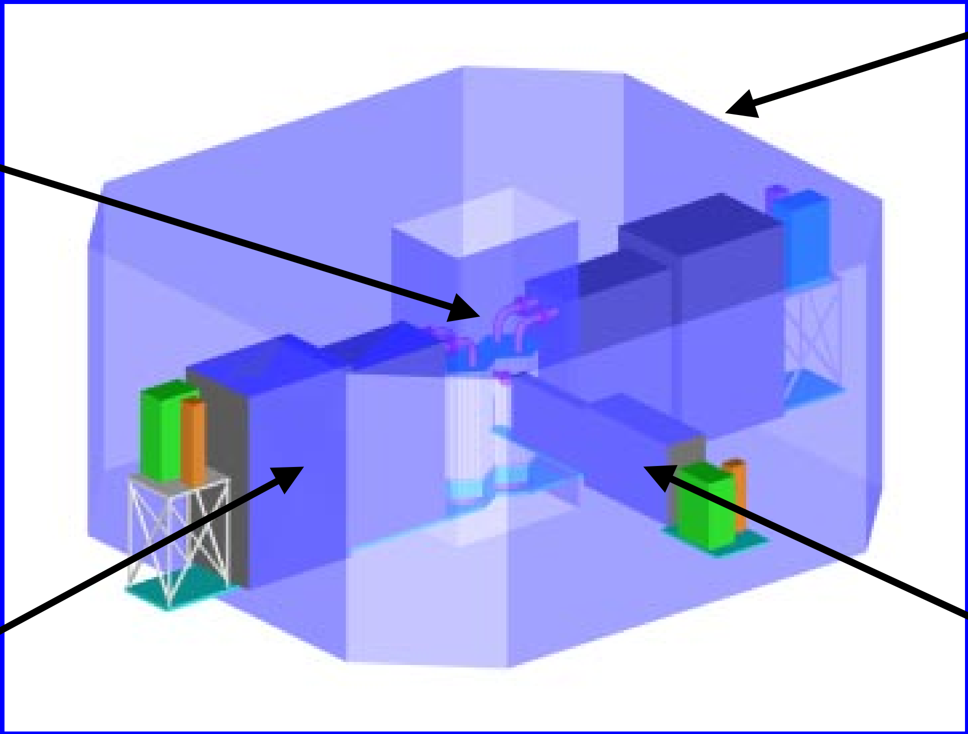
Conceptual ADTF layout



Modular concept for target and subcritical multiplier

Experiment Cell

Shield



Multiplier Assembly

Target Assembly

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Advanced Accelerator Applications AAA

ADTF benefits of the AAA Program

- Essential reactor constraints can be relaxed in subcritical systems
- Both steady state and transient modes
- Accelerator selection optimizes neutron production and proton range
- Drives 80-180 $MW_{thermal}$ subcritical blanket
- Demonstration of integrated system

The AAA Program will provide a sound foundation to ...

- Assess options for transmutation
- Develop a test bed for nuclear R&D
- Develop isotope production technology
- Strengthen nuclear infrastructure
- Improve prospects of a nuclear future